LATE PLEISTOCENE SEDIMENTARY ENVIRONMENT OF THE "HOMEB SILTS" DEPOSITS, ALONG THE MIDDLE KUISEB RIVER IN THE NAMIB DESERT, NAMIBIA

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ABSTRACT In the Namib, the tectonic and geographic setting of the area means that there are no large lake basins, and relict aeolian deposits appear to be quite rare. This has posed severe problems for reconstructing palaeoclimates in this region. In addition, there are significant problems with developing a well-dated chronology of events, as well as in the interpretation of the dated evidence for hydrologic and climatic changes. The Late Pleistocene "Homeb Silts" have been interpreted in previous studies as follows: (1) dune-damed lake sediments indicating an arid environment; (2) river end-point deposits indicating arid conditions; (3) flood plain sediments of an aggrading river indicating a semi-arid environment and (4) river flood slack water sediments indicating a wet environment and intense precipitation events in the headwaters. In this present study, sedimentary facies of the "Homeb Silts" were re-described and interpretation of the sedimentary environment changes that resulted in their deposition re-assessed. The conclusions are as follows: (1) The "Homeb Silts" were deposited during *ca.* 26 to 19 k yrs BP (*ca.* 25 to 19 k cal yrs BP) as indicated by eleven AMS ^{14}C measurements; (2) Almost all of the "Homeb Silts" were deposited under wet conditions by fluvial floods, except during the early depositional phase; (3) The "Homeb Silts" have recorded some detailed environmental changes during *ca.* 26 to 19 k yrs BP (*ca.* 25 to 19 k cal yrs BP); and, (4) Depositional events caused by similar climatic events in recent years have occurred, like heavy rains and flood events in the headwaters.

Key Words: Namib Desert; Kuiseb River; Slack water sediments; Sedimentary environment; Last Glacial Maximum (LGM); AMS radiocarbon dating; Palaeohydrology.

INTRODUCTION

Due to the lack of sediments in hyperarid to arid areas of the African Continent, there are fewer palaeoenvironmental change studies than for tropical and wetter areas. In the Namib, the tectonic and geographic setting of the area means that there are no large lake basins, and relict aeolian deposits appear to be quite rare (Bertram, 2000). This has posed severe problems for reconstructing palaeoclimates in this region. Additionally, there are significant problems with developing a well-dated chronology of events, as well as in the interpretation of the dated evidence for hydrologic and climatic changes (Lancaster, 2002).

The type locality of the "Homeb Silts" Formation is at Homeb, and sediments in this general area have been studied intensively (e.g., Marker, 1977; Vogel, 1982; Smith et al., 1993; Heine & Heine, 2002; Srivastava et al., 2006), particularly in regard to sediment characteristics, deposition process, and chronology. These Homeb Silts have been interpreted as follows: (1) dune-damed lake sediments indicating on arid environment (Groudie, 1972; Rust & Wienke, 1980); (2) river end-point deposits indicating arid conditions (Marker & Müller, 1978); (3) flood plain sediments of an aggrading river indicating a semiarid environment (Ward, 1987; Smith et al., 1993); and, (4) river flood slack water sediments indicating a wet environment and intense precipitations events in the headwaters (Heine & Heine, 2002).

In this present study, the sedimentary facies of the Homeb Silts were re-described and interpretation of sedimentary environment changes that resulted in their deposition re-accessed.

STUDY AREA AND METHOD

I. Study Area

The hyperarid to arid Namib Desert extends for over *ca.* 2,000km along the west coast of southern Africa from the Olifants River in South Africa (32°S) to the Carunjamba River (14°S) in Angola (Fig. 1). In inland, it is bounded by the Great Escarpment, which lies 120–200 km from the coast and forms the western edge of the interior plateau of southern Africa (Lancaster, 2002). The width of the desert varies between 40 and 120km.

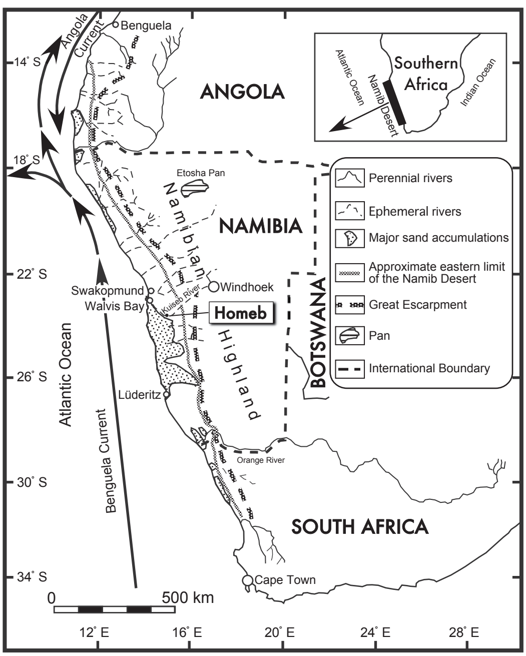

Fig. 1. The Namib Desert. Map showing sand accumulations and the locality of the studied site (modified from Heine & Heine, 2002).

The Kuiseb River is a westerly flowing ephemeral river in southern Namibia. It is 420km long and has a catchment area of 15,500km^2 (Jacobson et al., 1995). The headwaters of the Kuiseb River are in the central Namibian Khomas Highlands reaching 2,280masl. This area has a mean annual rainfall of ~335mm but only 5% of the catchment receives more than 300 mm/yr and only 52% more than 100mm/yr (Jacobson et al., 1995).

The Homeb Silts are distributed over *ca.* 62km of the Kuiseb River between Gomkaeb and Soutrivier (Ward, 1987: Figs. 2 & 3). The Homeb Silts

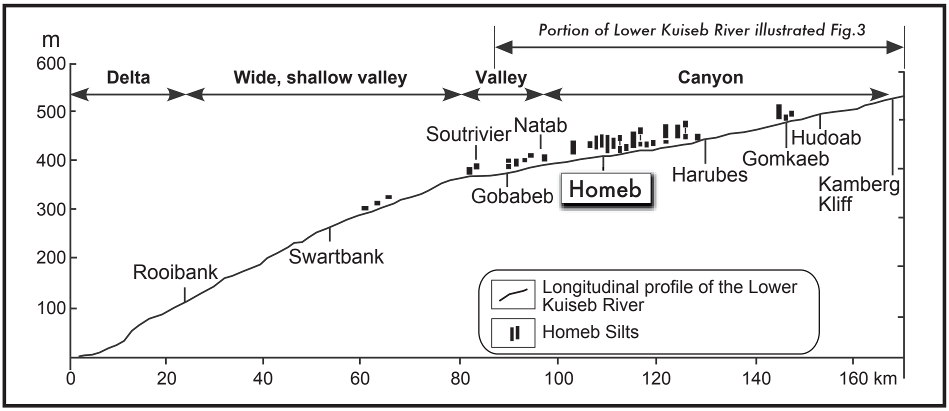

Fig. 2. Profile along the Kuiseb River and distribution of the Homeb Silts (modified from Ward, 1987; Heine & Heine, 2002).

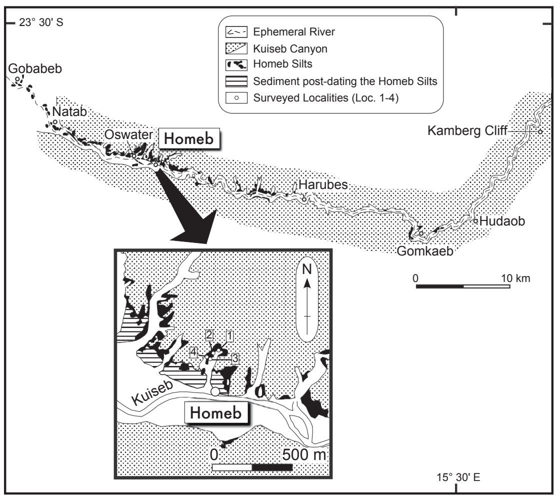

Fig. 3. Distribution of the Homeb Silts sediments of the Kuiseb River (modified from Ward, 1987; Heine & Heine, 2002).

are mostly preserved at the canyon section of the Kuiseb River as isolated castle-shaped outcrops in the main channel and as terraced flat-topped outcrops in tributaries joining the river from the gravel plains (Smith et al., 1993: Figs. 2 & 3). The Homeb Silts Formation in the middle Kuiseb valley consists of up to *ca.* 26m thickness of horizontally bedded micaceous yellowish brown to grey organic fine sand to silts, with interbedded coarse sand and red-brown sand. Relations between deposits of the different fluvial aggradations periods in the Kuiseb valley are shown schematically in Figure 4.

I examined the sedimentary structure and age of the organic sediments (including humus materials) at Homeb (Fig. 3). Here, the sediments are preserved as a series of terraces, where a single outcrop can be up to *ca.* 26m thick and up to *ca.* 45m above the present river bed.

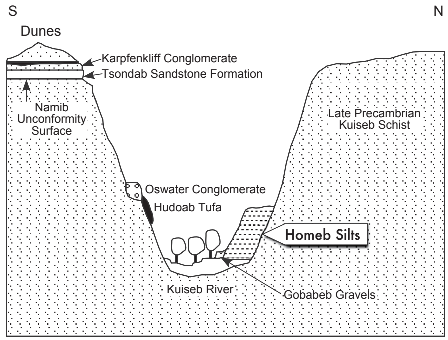

Fig. 4. Schematic cross section of the Kuiseb River in the vicinity of Homeb, showing geomorphic relations between major Quaternary fluvial deposits (modified from Seely & Ward, 2006).

II. Method

After careful observations, four thick sediment sequences were described in detail (Fig. 3). Locality 1 (20° 38' 3.9"S, 15° 11' 15.1"E; higher than Locality 2 to 4) is the highest, Locality 2 (20° 38' 0.02"S, 15° 11' 12.3"E), Locality 3 (same outcrop at Locality 2) and Locality 4 (same outcrop at Locality 2) are located in the lower sediment. The sedimentary facies and structure of each locality were described, and sediment samples were collected for AMS ^{14}C dating. Thirteen organic sediments materials were collected from exposed sites at the Homeb Silts. Conventional ^{14}C ages were determined for bulk organic sediment samples by Institute of Accelerator Analysis Ltd., Fukushima, Japan (IAAA). These organic sediments were chemically pre-treatmented by boiling with 1N HCL for 60min. The horizons that were dated are shown in Figure 5 with conventional ^{14}C ages. Calendar years were determinated dendrochronologically and calibrated with probable age ranges with confidence limits of 2σ. Calibration was carried out using the program CALIB Radiocarbon Calibration with data set of INTCAL04 (Stuiver et al., 2004). Percentages in parentheses show relative area under probability distribution.

RESULTS

I. Sedimentary characteristics of the Homeb Silts

Loc. 1 to Loc. 4 of a *ca.* 26m thick section of the Homeb Silts are shown in Figure 5 and Figures 6a to 6c. In generally, the Homeb Silts are mainly composed of very fine sand, silt-rich organic matter content from the cobble, with granules.

Sedimentary facies identification was based on basic sedimentary structure, grain size, and geometry of the various sedimentary units. Sedimentary units were classified as same Unit. Several sedimentary facies were identified and

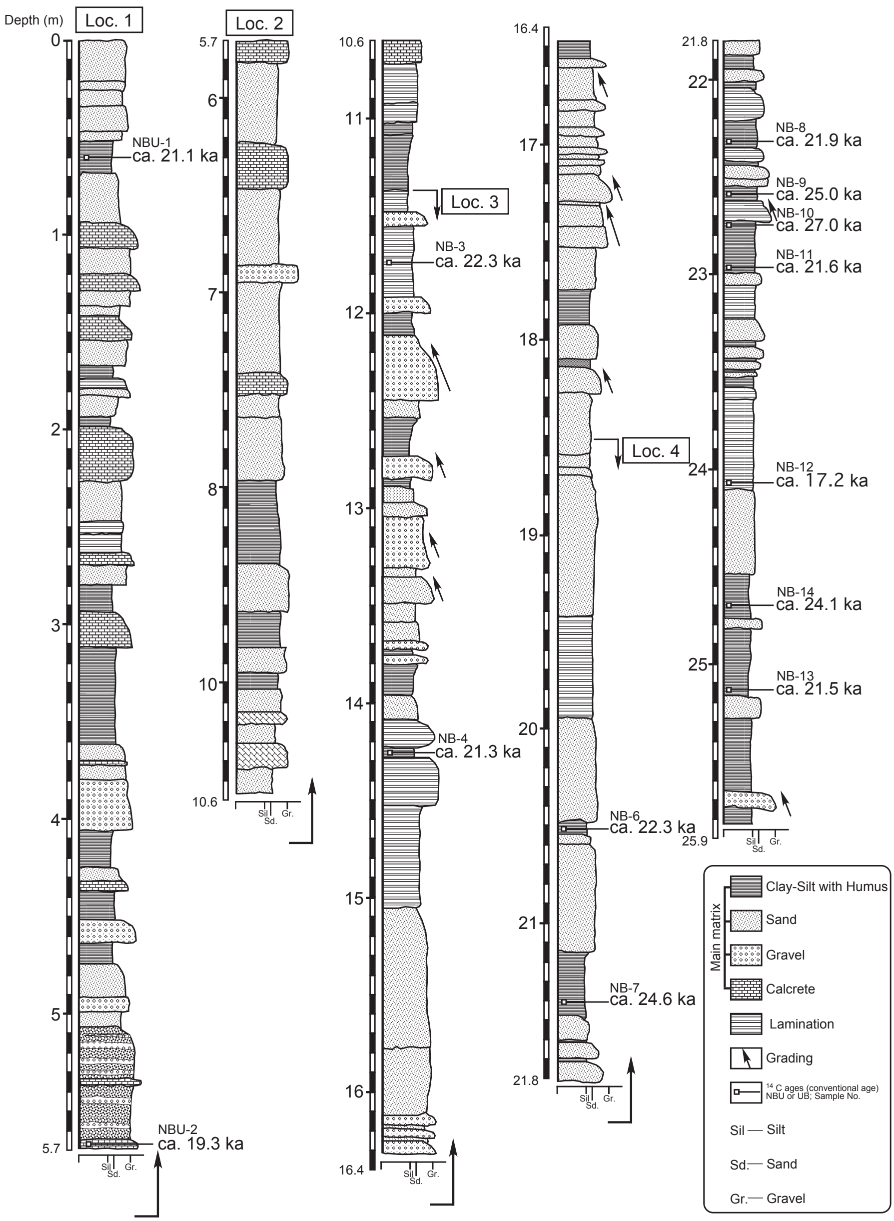

Fig. 5. Sedimentary facies and ^{14}C dates of Homeb Silt formation. ^{14}C dates showing conventional ages.

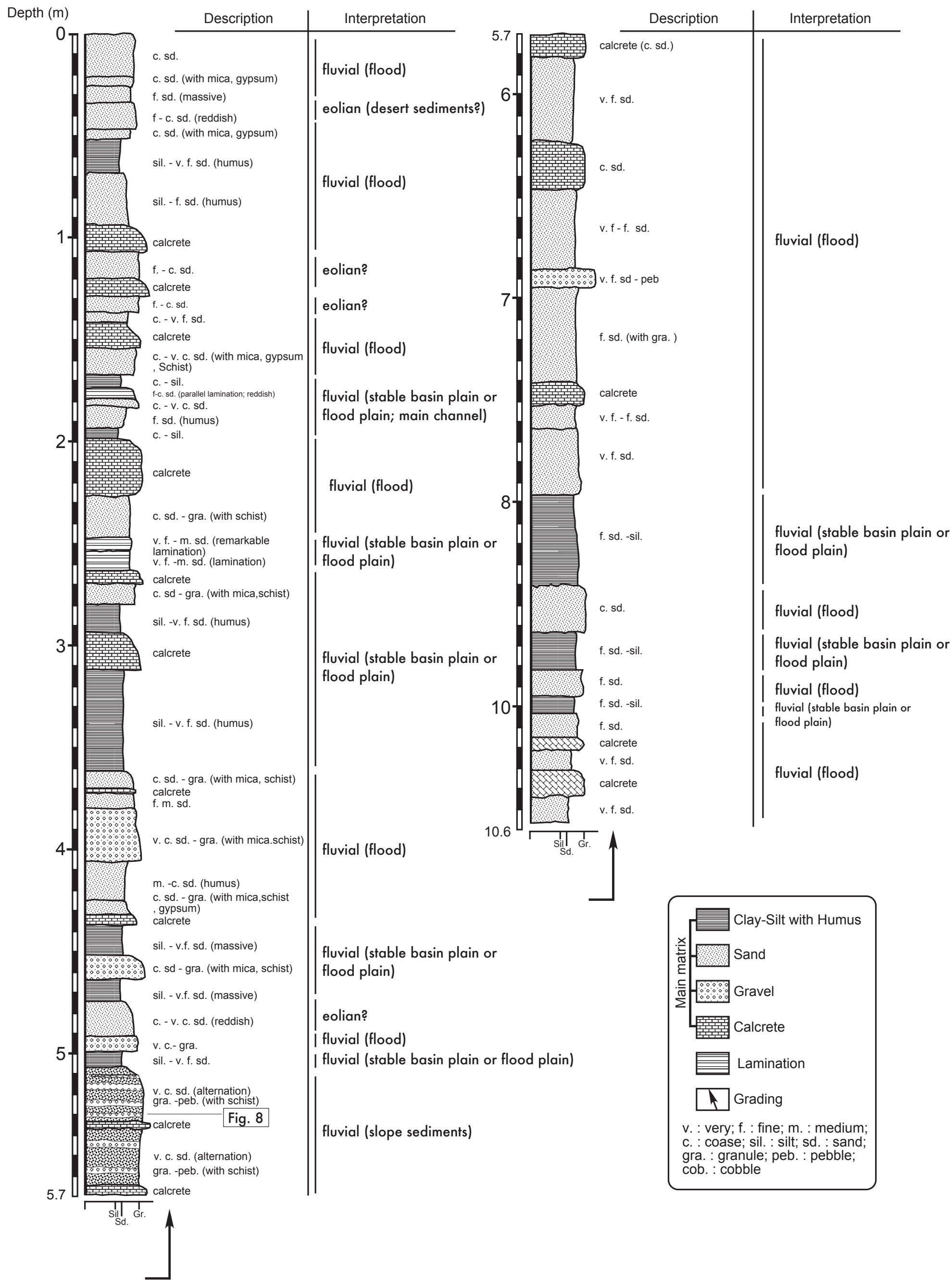

Fig. 6-a. Sedimentary facies and interpretation of the Homeb Silt formation.

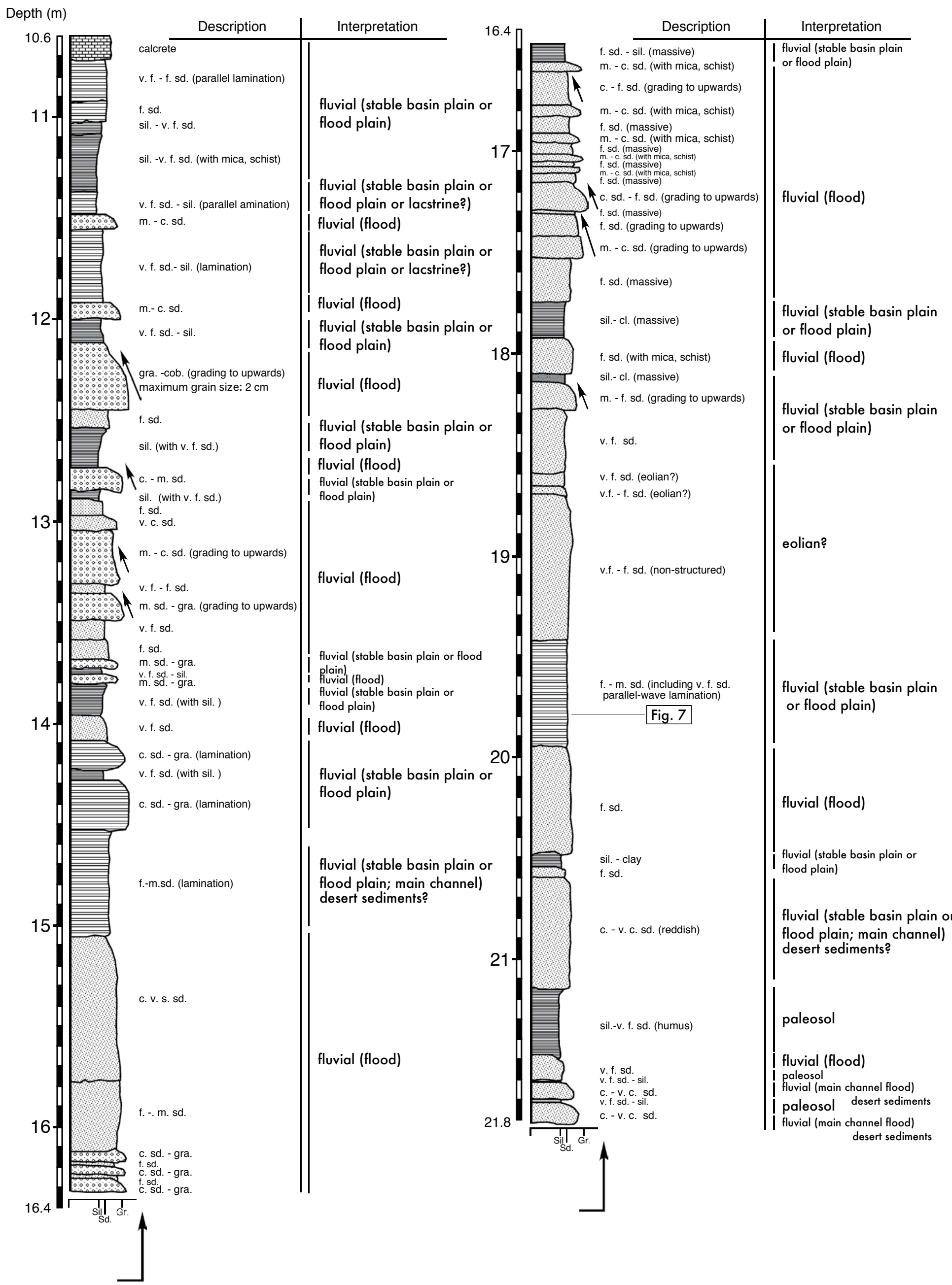

Fig. 6-b. (Continued) Sedimentary facies and interpretation of the Homeb Silts formation. The legend is the same as in Figure 6 - a.

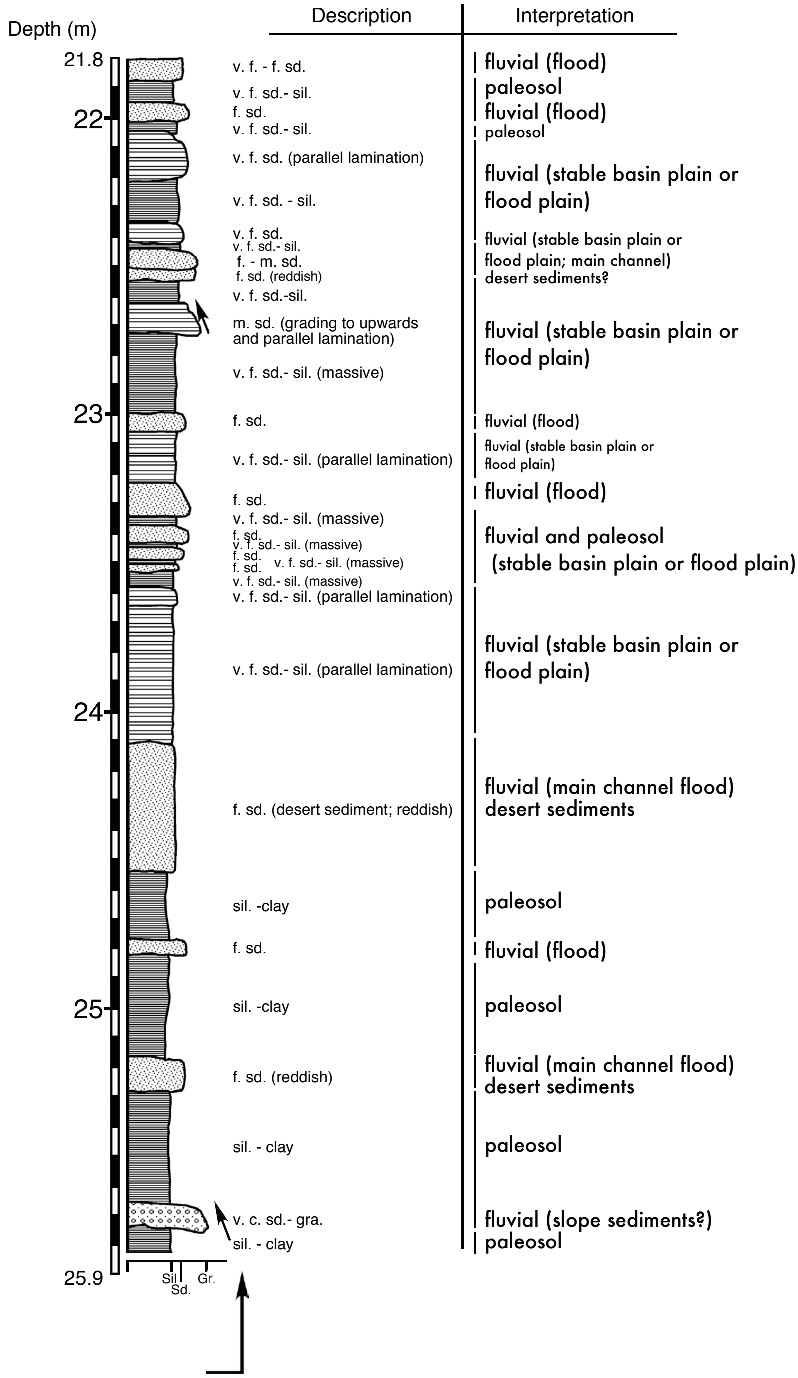

Fig. 6-c. (Continued) Sedimentary facies and interpretation of Homeb Silt formation. The legend is same as in Figure 6- a.

classified into the sedimentary sequences based on their vertical and lateral associations.

Individual sedimentary facies unit

Five principal sedimentary facies were identified in the Homeb Silts area:

1) Sand layer

Some of upwards to grading is the only structure is a clear structure deposition could not be observed, the better sorting mainly composed of fine sand, partially including gypsum, mica and schist. Also, at the top (up to 10m from the top), some calcrete had been formed.

2) Parallel-laminated layer

This is mainly composed of very fine sand and silt, as well as containing fine sand and medium sand horizons. Figure 7 partially shows a wavy laminated structure, but also indicates that most of the sedimentary structure is parallel bedding.

3) Non-structured sand layer

This is composed of very fine sand from a sand-based sediment and has clear lack of sedimentary structures. This layer is typically *ca.* 18.2m to 19.4m from the top of the section (Figs. 5 & 6).

4) Massive organic layer

This is mainly composed of very fine sand and silt. In particular, the basal to *ca.* 24.5m from top of the section contained organic-rich sediments. The samples taken for ^{14}C dating of were mainly from this horizon.

5) Alternation of sand and gravel layers

Figure 8 shows laminated very coarse sand and pebbles from the gravel at *ca.* 5.1 to 5.7m.

Fig. 7. Slope sediments at Locality 1. Stratigraphic point is shown in Figure 6. Left scale is 10cm.

Fig. 8. Wave-ripple lamination at Locality 4. Stratigraphic point is shown in Figure 6.

Table 1. The results of AMS radiocarbon dates from the Homeb Silts.

Sample No.	Material Dated*	Method	Measured ^{14}C age (y BP)	δ^{13} C (‰)	Conventional ^{14}C age (1σ; y BP)**	Calibrated age (cal y BP; 2σ)**Range (BC)***	Lab. No. (IAAA)****
NBU-1	Organic Sediment	AMS	20,910±100	-16.79±0.62	21,050±100	>23,963 (1.8 %) 23,700-22,900 (93.6 %)	72729
NBU-2	Organic Sediment	AMS	19,120±90	-16.07±0.70	19,270±90	21,400-20,550 (95.4 %)	72730
NB-3	Organic Sediment	AMS	22,170±90	-18.70±0.61	22,280±90	20,520-20,140 (95.4 %)	61591
NB-4	Organic Sediment	AMS	21,310±80	-24.28±0.61	21,320±80	>23,580 (95.4 %)	61592
NB-6	Organic Sediment	AMS	22,180±90	-19.82±0.57	22,260±90	20,500-20,120 (95.4 %)	61593
NB-7	Organic Sediment	AMS	24,450±100	-14.66±0.47	24,620±100	22,880-22,470 (95.4 %)	73097
NB-8	Organic Sediment	AMS	21,740±80	-18.51±0.62	21,850±90	20,080-19,720 (95.4 %)	61594
NB-9	Organic Sediment	AMS	24,930±110	-18.37±0.60	25,040±110	23,320-22,870 (95.4 %)	73098
NB-10	Organic Sediment	AMS	26,830±110	-16.55±0.65	26,970±110	25,250-24,800 (95.4 %)	73099
NB-11	Organic Sediment	AMS	21,530±80	-18.34±0.59	21,640±80	19,860-19,540 (95.4 %)	61595
NB-12	Organic Sediment	AMS	17,070±60	-16.90±0.62	17,200±60	18,580-18,140 (95.4 %)	73100
NB-13	Organic Sediment	AMS	21,510±80	-22.24±0.69	21,550±90	19,790-19,430 (95.4 %)	61596
NB-14	Organic Sediment	AMS	23,910±100	-15.96±0.67	24,050±100	22,310-21,890 (95.4 %)	73101

* Chemical pre-treatment: boiling with 1N HCL for 60 min. .

** Conventional ^{14}C ages were corrected by δ13C and calculated using the Libby half-life 5568 years.

*** Calendar years were determinated dendrochronologically calibrated probable age ranges with confidence limits of 2 σ. Calibration was carried out using a program CALIB Radiocarbon Calibration (http://calib.qub.ac.uk/calib/) with data set of INTCAL04 (Stuiver et al., 2004). Percentages in parentheses shows relative area under probability distribution.

**** IAAA: Institute of Accelerator Analysis Ltd. , Fukushima, JAPAN.

II. Radiocarbon dates

Table 1 shows the AMS ^{14}C age results of the thirteen organic sediment samples, which range from *ca.* 27,000 yr BP (NB-10; IAAA-73099) to *ca.* 1,7000 yr BP (NB-12; IAAA-73100). However, NB-12 age was reported that the less of carbon contents by IAAA. For the reasons mentioned above, the age variation between the top and bottom sediments indicate ages of *ca.* 27,000 yr to 19,000 yr BP, with the exception of NB-12.

The oldest calibration age in this study is *ca.* 25.3 cal yr BP (NB-10: IAAA-73099) and the youngest value is *ca.* 19.4 cal yr BP (NB-13: IAAA-61596), except for NB-12, as mentioned above. Judging from these results the ^{14}C age of organic sediments of the Homeb Silts range from *ca.* 25.3 to 19.4 k cal yr BP. The reverse ages are the allowable margin of error.

DISCUSSION

Based on the above results, I will discuss the sedimentary environments and the palaeohydrology of the Homeb Silts and surrounding areas in the following sections.

I. Chronology and sedimentary environments of the Homeb Silts

Previous chronological studies of the Homeb Silts reported ages of *ca.* 2.3 to 1.9 k yr BP based on shell samples (Vogel, 1982), and calibration calendar ages of *ca.* 2.7 to 2.2 k cal yr BP (Bard et al., 1990; 2004; Hughen et al., 2004). In addition, the age of the basal sand layer was reported as *ca.* 23.3 ± 3.2 k BP, and *ca.* 19.3 ± k BP using the TL (Thermo Luminescence) method (Eitel & Zöller, 1996).

However, the Homeb Silts were deposited during *ca.* 9.8 to 6.3 ka (Bourke et al., 2003) and intense deposition happened until *ca.* 15 ka and 6.3 ka (Srivastava et al., 2006) were reported by OSL (Optically Stimulated Luminescence) method recently. However, almost all ^{14}C ages of the Homeb Silts in this study range from *ca.* 27 to 19 k yrs BP (*ca.* 25 to 19 k cal yr BP: Table 1) and these ages are consistent with previous ^{14}C and TL ages. Therefore, I will discuss the above ages in the next section.

I will discuss the changes of the sedimentary environments of the Homeb Silts, for each sedimentary unit described in the previous section. In addition, Figure 6 shows detail interpretations of the sedimentary environments. Moreover, Figure 9 shows the changes of sedimentary environments of the Homeb Silts based on the above section.

Sand layer

Some upward grading structures are observed, which indicates fluvial sediments. However, in this study, I did not observe the channel deposit structure reported in Strivastava et al. (2006). It is suggested that this unit was deposited by tributary fluvial processes because of the inclusion of sand dunes or sand sea sediments from the southern part of the Namib Desert. Therefore, this unit was recognized as being deposited by fluvial processes mainly by a tributary channel.

Conversely, sand dunes and sand sea sediments are contained in these facies that suggest main channel flooding. The calcrete at the top (10m in depth) was formed by a temporary water-bearing formation in a dry phase at the Pakistan

(Waragai, 2005). Therefore, this unit is formed during wet environment under a temporary dry conditions.

Eitel et al. (2006) suggested that the calcrete formation indicates past soilization associated with the surface of the soil and decreasing precipitations. It is clear that floods occurred frequently in an environment with a temporary dry phase. Additionally, Strong et al. (1992) indicated that calcrete is formed under a humid climate. However, the calcrete layer is associated with fluvial flood sediments, and therefore it is inconsistent with the long-term dry phase in this study. These characteristics reflect the fact that the calcretes formed in a relatively near-surface environment with relatively high rates of evaporation (David et al., 2003). Therefore, this unit sediment is deposited under the fluvial environments.

Parallel-laminated layer

Smith et al. (1993) and Strivastava et al. (2006) also indicated that the Homeb Silts formation was described in several sites along the Kuiseb River. These sedimentary facies were formed in floodplain and lacustrine environments by a stable environment (Miall, 1996).

Non-structured sand layer

These sediments are mainly composed of unconsolidated, non-structured and unsorted, very fine to fine sands suggesting aeolian deposition. However, evidence is not clear and it is difficult to discriminate these sediments from fluvial sediments.

Massive organic layer

Organic-rich sediment is observed at *ca.* 24.5m and lower from the top of the section. This sediment indicates that the flooded by relatively stable environment deposited, and then were progressed the soilization formed under the surface during the dry phase. It is difficult to discuss on in situ formation of as a described “bioturbated clayey silt” (Strivastava et al., 2006), because this sediment was formed after primary deposition. However, it is consistent with in this study that this sediment was deposited in a stable sedimentary environment (Strivastava et al., 2006).

Alternation of sand and gravel layers

This sedimentary facies is composed of unsorted coarse-grained sediments that indicate slope sediments of fluvial tributaries.

II. Palaeohydrologic and palaeoclimatic implications

Figure 9 shows the change of the sedimentary environments during *ca.* 27 to 19 k yr BP (*ca.* 25 to 19 k cal yr BP). It is clear that almost all of the *ca.* 26m thick section of fine-grained sediments was deposited by mainly fluvial processes. However, paleosols are deposited in the early stage, and aeolian sediments indicate short-term environmental fluctuations.

Thus, this study suggests that the *ca.* 26m of the Homeb Silts were deposited during the *ca.* 2.5–1.9 k cal yr BP at the early stages of a dry phase as a transition period.

In other words, after *ca.* 2.5–1.9 k cal yr BP, fine-grained sediments deposited along the Kuiseb river, were eroded along the left side by the main channel and the Homeb Silts were preserved mainly along the right bank (Fig. 3).

I will discuss the changes of sedimentary environments of the Homeb Silts in detail. Heine & Heine (2002), and Heine (2004) suggested that the Homeb Silts represent a series of “slack water deposits” and envisaged floods rising to more than 45m above the level of the present channel between *ca.* 23 to 19 ka BP. Slack water deposits are typically composed of fine-grained sand and silt that settle out in an area of reduce flow velocity during large floods (Baker, 1987). In fact, these characteristic sediments are also observed in this study and previous studies (Strivastava et al., 2006). However, paleosol sediments of the early stage of deposition indicate a relatively dry environment. Therefore, there is no evidence that the Homeb Silts were deposited by slack water as long-term

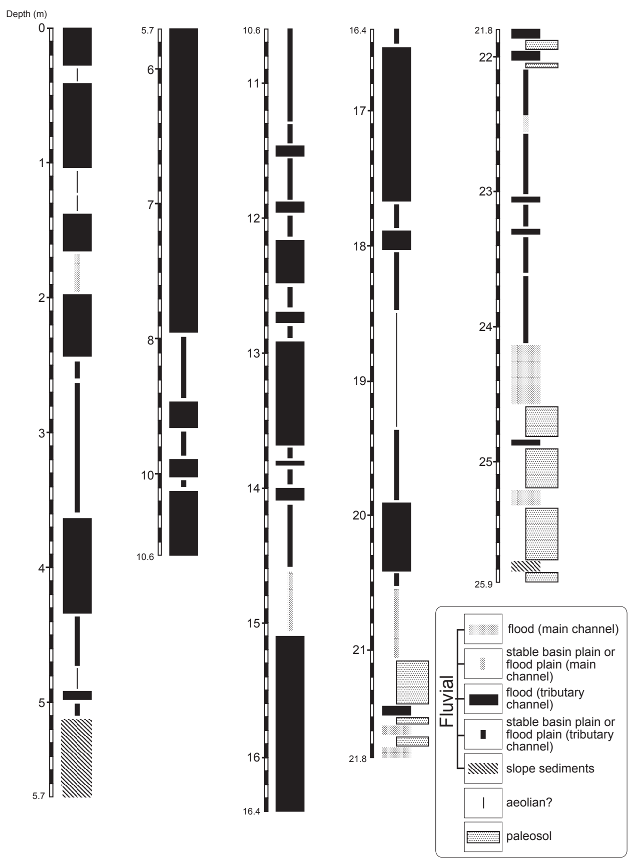

Fig. 9. The change of sedimentary environments and palaeohydrology in the vicinity of the Homeb.

water conditions throughout the time.

Therefore, it seems reasonable to conclude that some unexpected floods (discharge) and a stable expansion of a wet environment occurred, because of the existence of slope sediments and a stable phase of sediments rather than slack water deposits that were deposited during long-lasting wet phase flooding.

According to a review of palaeoenvironmental studies focused on the Namib Desert (Lancaster, 2002), the causes of the above environment was the increase of summer rain precipitation and the increase of ephemeral river activities around the eastern part of the Escarpment rather than an increase of winter precipitation. In this study, it is difficult to compare with other sites, but, a wet phase was reported around Gobabeb in the reconstruction of the landform developments in the vicinity of Homeb *ca.* 22 k BP (Yamagata & Mizuno, 2005). Therefore, it is necessary to discuss on the change of the sedimentary environments of the Homeb Silts were correlated with other sites.

An increase in summer rain precipitation for the current climate as indicated by climate models (e.g., Cockcroft, et al., 1987) and reports of heavy rain and flooding that have occurred in recent years (Kadomura, 2005a; 2005b), may have occurred during similar climatic change in the past.

CONCLUSIONS

In this study, sedimentary facies of the Homeb Silts were re-described and interpretation of the sedimentary environment changes that resulted in their deposition re-assessed. The conclusions are as follows: (1) The Homeb Silts were deposited during *ca.* 26 to 19 k yrs BP (*ca.* 25 to 19 k cal yrs BP) as indicated by eleven AMS ^{14}C measurements; (2) Almost all of the Homeb Silts were deposited under wet conditions by fluvial floods, except during the early depositional phase; (3) The Homeb Silts have recorded some detailed environmental changes during *ca.* 26 to 19 k yrs BP (*ca.* 25 to 19 k cal yrs BP); and, (4) Depositional events caused by similar climatic events in recent years have occurred, like heavy rains and flood events in the headwaters.

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REFERENCES

Baker, V.R. 1987. Paleoflood hydrology and extreme flood events. *Journal of Hydrology*, 96: 79-99.

Bard, E., B. Hamelin, R.G. Fairbanks & A. Zindler 1990. Calibration of the ^{14}C timescale over the past 30,000 yr using mass spectrometric U-Th ages from Barbados corals. *Nature*, 345: 405-410.

Bard, E., F. Rostek, G. Ménot-Combes 2004. Radiocarbon calibration beyond 20,000 ^{14}C yr BP by mean of planktonic foraminifera of the Iberian margin. *Quaternary Research*, 61: 204-214.

Bertram, S. 2000. Fluvio-aeolian sand ramps-a key to Quaternary landscape evolution in Namibia. In (N. Lancaster & V.P. Tchakerian, eds.) *IGCP 413 Workshop: Linkages between fluvial, Lacstrine, and Aeolian System*, pp. 23-27. Desert Research Institute, Desert Studies Center, Zzyzx, CA.

Bourke, M.C. & A.C.S. Srokes 2003. Optical age estimates for hyper-arid fluvial deposits at Homeb, Namibia. *Quaternary Science Reviews*, 22: 1099-1103.

Cockcroft, M.J., M.J. Wilkinson & P.D. Tyson 1987. The application of a present: Day climatic model to the Late Quaternary in Southern Africa. *Climatic Change*, 10: 161-181.

David J.N. & S.J. McLaren 2003. Kalahari valley calcretes: Their nature, origins, and environmental significance. *Quaternary International*, 111: 3-22.

Eitel, B. & L. Zöller 1996. Soils and sediments in the basin of Diepriver-Uitskot (Khoriax District, Namibia) age, geomorphic and sedimentlogical investigation, paleoclimatic interpretation. *Palaeoecology of Africa*, 24: 159-172.

Eitel, B., A. Kadereit, W.D. Blümel, K. Hüser, J. Lomax & A. Hilgers 2006. Environmental changes at the eastern Namib desert margin before and after the last Glacial Maximum: New evidence from fluvial deposits in the upper Hoanib river catchment, northwestern Namibia. *Palaeoecology, Palaeoclimatology, Palaeoecology*, 234: 201-222.

Groudie, A. 1972. Climate, weathering, crust formation, dunes and fluvial features of Central Namib Desert, near Gobabeb, Southwest Africa. *Madoqua*, 1: 15-31.

Heine, K. & J.T. Heine 2002. A paleohydrologic re-interpretation of the Homeb Silts. Kuiseb River, central Namib Desert (Namibia) and paleoclimatic implications. *Catena*, 48: 107-130.

Heine, K. 2004. Flood reconstructions in Namib Desert, Namibia and Little Ice Age climatic Implications: Evidence from Slack water deposits and desert soil sequences. *Journal of Geological Society of India*, 64: 535-547.

Hughen, K., S. Lehman, J. Southon, J. Overpeck, O. Marchal, C. Herring & J. Turnbull 2004. ^{14}C activity and global carbon cycle changes over the past 50,000 years. *Science*, 303: 202-207.

Jacobson, P.J., K.M. Jakobson & M.K. Seely 1995. *Ephemeral Rivers and Their Catchment: Sustaining People and Development in Western Namibia*. Desert Research Foundation of Namibia, Windhoek.

Kadomura, H. 2005a. Heavy rains and flood disasters occurred during 2003 in Africa (in Japanese). *Chikyu Kankyou*, 10(1): 29-40.

——— 2005b. Climate anomalies and extreme events in Africa in 2003, Including heavy rains and floods that occurred during northern hemisphere summer. *African Study Monographs Supplementary Issue*, 30: 165-181.

Lancaster, N. 2002. How dry was dry? -Late Pleistocene palaeoclimates in the Namib Desert. *Quaternary Science Reviews*, 21: 762-782.

Marker, M.E. 1978. Aspects of the geomorphology of the Kuiseb River, South West Africa. *Madoqua*, 10: 199-206.

Marker, M.E. & D. Müller 1978. Relict vlei silts of the middle Kuiseb River valley, South West Africa. *Madoqua*, 11: 151-162.

Miall, A.D. 1996. *The Geology of Fluvial Deposits*. Springer, Berlin.

Rust, U. & F. Wienke 1980. A investigation of some aspects of the evolution of the Kuiseb River valley upstream of Gobabeb, South West Africa. *Madoqua*, 12: 163-173.

Seely, M.K. & J.D. Ward 2006. *Dunes 2006. Excursion Field Guide; Ecological Aspects of Dune in the Central Namib Desert*. Desert Research Foundation of Namibia (DRFN), Windhoek.

Smith, R.M.H., T.R. Marson & J.D. Ward 1993. Flash flood sediments and ichnofacies of the Late Pleistocene Homeb Silts, Kuiseb River, Namibia. *Sedimentary Geology*, 85: 579-599.

Srivastava, P., G.A. Brook, E. Mararis, P. Morthekari & A.K. Singh 2006. Depositional environment and OSL chronology of the Homeb silt deposits, Kuiseb River, Namibia. *Quaternary Research*, 65: 478-491.

Strong, G.E., J.R.A. Giles & V.P. Wright 1992. A Holocene calcrete from North Yorkshire, England: Implications for interpreting palaeoclimates using calcretes. *Sedimentology*, 39: 333-347.

Stuiver, M., P.J. Reimer & R. Reimer 2004. CALIB Radiocarbon calibration, execute version 5.0.2html, http://calib.qub.ac.uk/calib/. (Accessed March 25, 2008)

Vogel, J.C. 1982. The age of Kuiseb River silt terrace at Homeb. *Palaeoecology of Africa*, 15: 201-209.

Ward, J.D. 1987. The Cenozoic succession of Kuiseb Valley, central Namibia. *Pale geography, Paleoclomatology, Paleoecology*, 70: 355-366.

Waragai, T. 2005. Holocene calcrete crust deposits on the moraine of Batura glacier, northern Pakistan. *The Island Arc*, 14: 368-377.

Yamagata, K. & K. Mizuno 2005. Landform development along the middle course of the Kuiseb River in the Namib Desert, Namibia. *African Study Monographs Supplementary Issue*, 30: 15-25.

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